Deciphering principles of morphogenesis from temporal and spatial patterns on the integument.

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Public Summary:
How tissue patterns form in development and regeneration is a fundamental issue remaining to be fully understood. The integument often forms repetitive units in space (periodic patterning) and time (cyclic renewal), such as feathers and hairs. Integument patterns are visible and can be tested experimentally, helping us reveal pattern forming processes. Phenotypic differences can be in different regions and different physiological stages. Here we explore some cellular/molecular reasons that establish skin patterning. (1) Localized cell behavior (proliferation, rearrangement, apoptosis, differentiation) transforms organ primordia into specific shapes. Combining these behaviors at specific locations can generate diverse and complex organ forms. (2) Competitive equilibrium between activators and inhibitors of skin appendage (hair, feather, beak, nail, etc) regeneration controls the cyclic quiescence or activation of their stem cells. This can be influenced by dynamic interactions between stem cells and their adjacent niche which can also be modulated by outside factors (present in the dermis, body hormone status, and external environment). In vivo skin imaging and lineage tracing unveils new insights into stem cell plasticity. Principles of self-assembly obtained from the skin model can be applied to restore appropriate patterning during regenerative wound healing and to rebuild organs through tissue engineering.

Scientific Abstract:
BACKGROUND: How tissue patterns form in development and regeneration is a fundamental issue remaining to be fully understood. The integument often forms repetitive units in space (periodic patterning) and time (cyclic renewal), such as feathers and hairs. Integument patterns are visible and experimentally manipulatable, helping us reveal pattern formative processes. Variability is seen in regional phenotypic specificities and temporal cycling at different physiological stages. RESULTS: Here we show some cellular/molecular bases revealed by analyzing integument patterns. (1) Localized cellular activity (proliferation, rearrangement, apoptosis, differentiation) transforms prototypic organ primordia into specific shapes. Combinatorial positioning of different localized activity zones generates diverse and complex organ forms. (2) Competitive equilibrium between activators and inhibitors regulates stem cells through cyclic quiescence and activation. CONCLUSIONS: Dynamic interactions between stem cells and their adjacent niche regulate regenerative behavior, modulated by multi-layers of macro-environmental factors (dermis, body hormone status, and external environment). Genomics studies may reveal how positional information of localized cellular activity is stored. In vivo skin imaging and lineage tracing unveils new insights into stem cell plasticity. Principles of self-assembly obtained from the integumentary organ model can be applied to help restore damaged patterns during regenerative wound healing and for tissue engineering to rebuild tissues. Developmental Dynamics 244:905-920, 2015. (c) 2015 Wiley Periodicals, Inc.